Exploration Transportation Strategic Roadmap Meeting

Space Operations Mission Directorate Overview

February 3, 2005

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Launch Services

Space Operations Mission Directorate

LAUNCH SERVICES

- **Safely Return the Space Shuttle to Flight**
- **Provide Safe, Reliable, On-time Cost Effective Assured Access to Space and Space Communications Systems to enable NASA missions - Moon, Mars, Beyond**
- **Completion of the ISS as a stepping stone to accomplishment of the Space Exploration Vision**
- **Seek areas of synergy with government user community**

Space Operations is More than a Launch Vehicle

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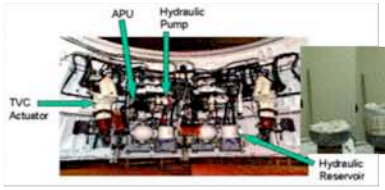
Design and Engineering



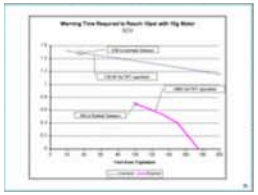
Component Evaluation

Assembly Evaluation

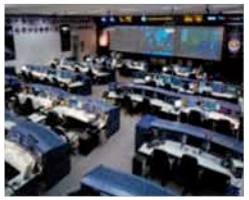
System Evaluation

Component Test

Full Up Test



Flight Design



Mission Planning

Crew Training

Mission Support

Flight Operations

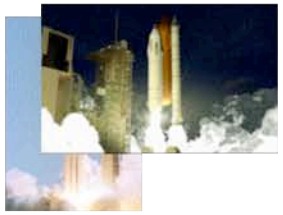
Command Communication Guidance

Management and Acquisition of Launch Services

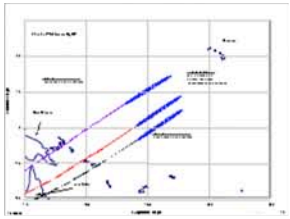
Assembly, Test, and Processing of Spacecraft

Launch Vehicle Processing

Vehicle Integration



Launch Scheduling
Launch Preparation
Launch Operations



Range Operations

Return/ Recovery Operations (as required)

NASA Launch Alternatives

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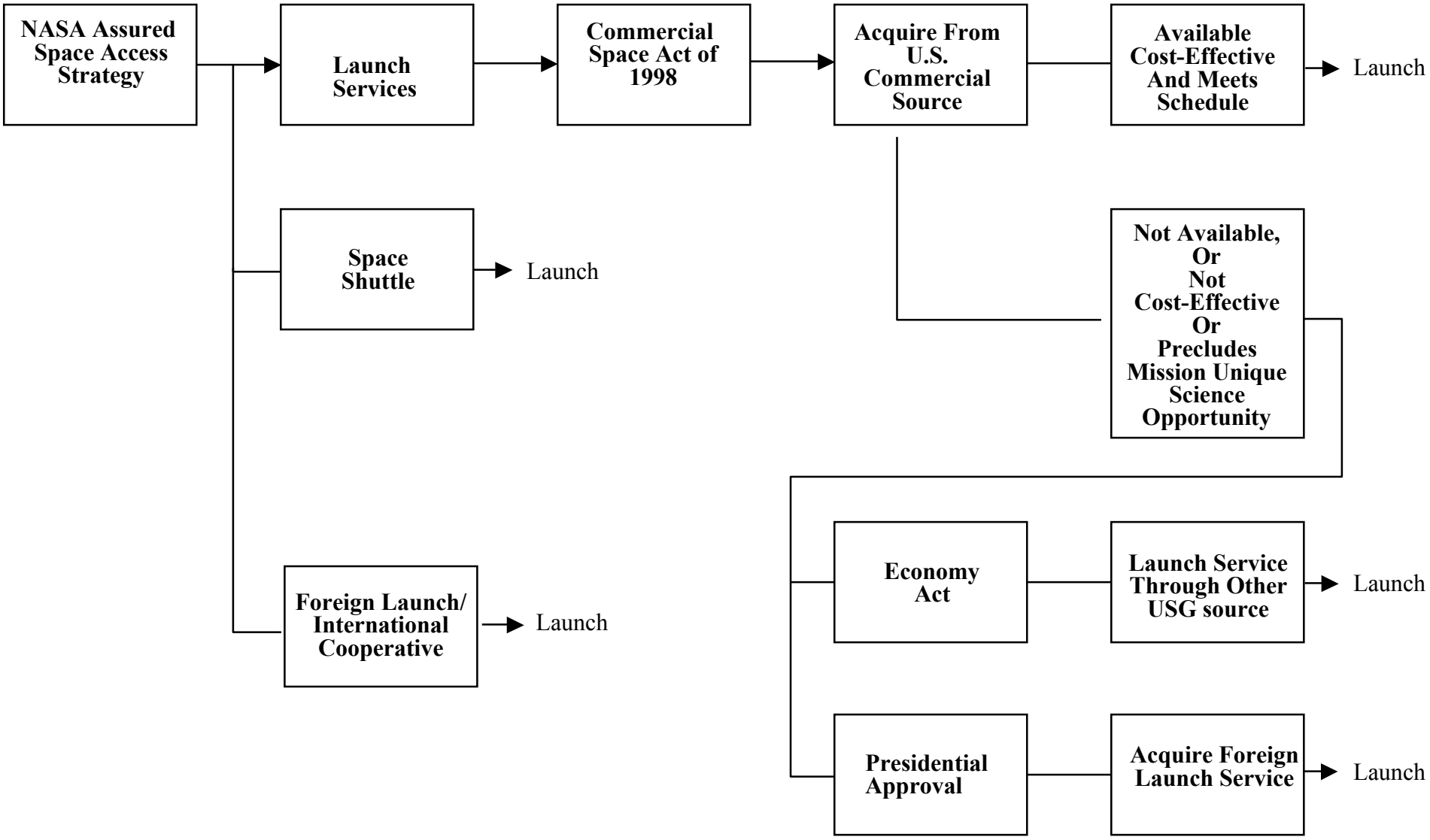


Mixed Fleet

- **Accomplishment of Space Exploration Vision and NASA mission has an inherent dependence on safe, reliable, cost effective, on time space access**
- **NASA employs a Mixed Fleet Launch Strategy to diversify space access across all available commercial launch systems as a lessons learned from Challenger and revalidated post Columbia**
- **Customers seek to take advantage of full range of space access:**
  - **OSO provides Shuttle and US ELV's and ISS**
  - **Sounding rockets, balloons, drop flights managed by Science Directorate**
  - **International cooperative launches, partner contributed services to ISS, potentially to Space Exploration**
  - **Emerging launch capability**
- **Challenge is balancing the requirements of diverse customer base with reality of stagnant external market conditions**

Key Space Transportation Legislative Direction

Launch Services Purchase Act of 1990

- Directed NASA to acquire commercial space launch services to meet the Agency launch requirements with noted exceptions

42 USC 14731 – Commercial Space Act of 1998 (P.L. 105-303)

- Retained earlier legislative direction and broadened application to all government users
- USG shall acquire space transportation services from United States commercial providers
- U.S. commercial provider defined as U.S. company more than 50% owned by U.S. nationals, or a U.S. subsidiary of a foreign company with past evidence of substantial investment in U.S. and the foreign country offers reciprocal opportunity for domestic subsidiaries of U.S. companies to participate in similar procurements by the foreign government

50 USC 1701 – Iran Nonproliferation Act of 2000 (P.L. 106-178)

- No USG agency may make extraordinary payments in connection with the International Space Station to certain Russian entities without a Presidential determination
- Extraordinary payments means payments in cash or in kind made for work on the ISS or for the purchase of any goods or services relating to human space flight

National Space Transportation Policy

President Signed the National Space Transportation Policy (NSTP) in December 2004

- **The fundamental goal of this policy is to ensure the capability to access and use space in support of national and homeland security, civil, scientific, and economic interests. To achieve this goal, the United States Government shall:**
  - Ensure the availability of U.S. space transportation capabilities necessary to provide reliable and affordable space access, including access to, transport through, and return from space
  - Develop space transportation capabilities to enable human space exploration beyond low Earth orbit, consistent with the direction contained in National Security Presidential Directive-31, U.S. Space Exploration Policy, dated January 14, 2004
  - Sustain a focused technology development program for next-generation space transportation capabilities that dramatically improves the reliability, responsiveness, and cost of access to, transport through, and return from space, and enables a decision to acquire these capabilities in the future
  - Encourage and facilitate the U.S. commercial space transportation industry to enhance the achievement of national security and civil space transportation objectives, benefit the U.S. economy, and increase the industry's international competitiveness
  - Sustain and promote a domestic space transportation industrial base, including launch systems, infrastructure, and workforce, necessary to meet ongoing United States Government national security and civil requirements

NSTP: Assured Access

- "Assured access" is a requirement for critical national security, homeland security, and civil missions and is defined as a sufficiently robust, responsive, and resilient capability to allow continued space operations, consistent with risk management and affordability.

- The Administrator of the National Aeronautics and Space Administration shall be the launch agent for the civil sector and shall maintain the capability to develop, evolve, operate, and purchase services for those space transportation systems, infrastructure, and support activities necessary to meet civil requirements, including the capability to conduct human and robotic space flight for exploration, scientific, and other civil purposes.

- The National Aeronautics and Space Administration shall engage in development activities only for those requirements that cannot be met by capabilities being used by the national security or commercial sectors.

NSTP: Evolved ELV (EELV)

- The capabilities developed under the Evolved Expendable Launch Vehicle program shall be the foundation for access to space for intermediate and larger payloads for national security, homeland security, and civil purposes to the maximum extent possible consistent with mission, performance, cost, and schedule requirements

- Any department or agency seeking to significantly modify or develop new launch systems derived from the Evolved Expendable Launch Vehicles or its major components, including human rating, shall be responsible for any necessary funding arrangements and shall coordinate with the Secretary of Defense and, as appropriate, the Secretaries of Commerce and Transportation and the Administrator of the National Aeronautics and Space Administration.

NSTP: U.S. Space Transportation

- **United States Government departments and agencies shall purchase commercially available U.S. space transportation products and services to the maximum extent possible, consistent with mission requirements and applicable law**

- **A viable domestic industrial and technology base is the foundation of a successful U.S. space transportation capability and is critical to assuring access to space for national security and civil purposes. To assure access to space and ensure national security and civil space transportation needs will continue to be met in the future:**

  - United States Government payloads shall be launched on space launch vehicles manufactured in the United States, unless exempted by the Director of the Office of Science and Technology Policy, in consultation with the Assistant to the President for National Security Affairs.

  - This policy does not apply to use of foreign launch vehicles on a no-exchange-of-funds basis to support the following: flight of scientific instruments on foreign spacecraft, international scientific programs, or other cooperative government-to-government programs.
  - The proposed use of a non-U.S.-manufactured launch vehicle will be subject to interagency coordination which will take into account national security and foreign policy concerns, civil and scientific interests, and the performance, availability, and economic and budgetary considerations associated with use of the proposed launch vehicle.

NSTP: International Participation

- The use of foreign components or technologies, and the participation of foreign governments and entities, in current and future U.S. space transportation systems is permitted consistent with U.S. law and regulations, as well as nonproliferation, national security, and foreign policy goals and commitments and U.S. obligations under the Strategic Arms Reduction Treaty, Intermediate Nuclear Forces Treaty, and the Missile Technology Control Regime.
- Such use or participation will not be permitted where it could result in critical national security or civil space launches being jeopardized by delays or disruptions in receipt of foreign-produced systems, components, technology, or expertise.

NSTP: Space Exploration

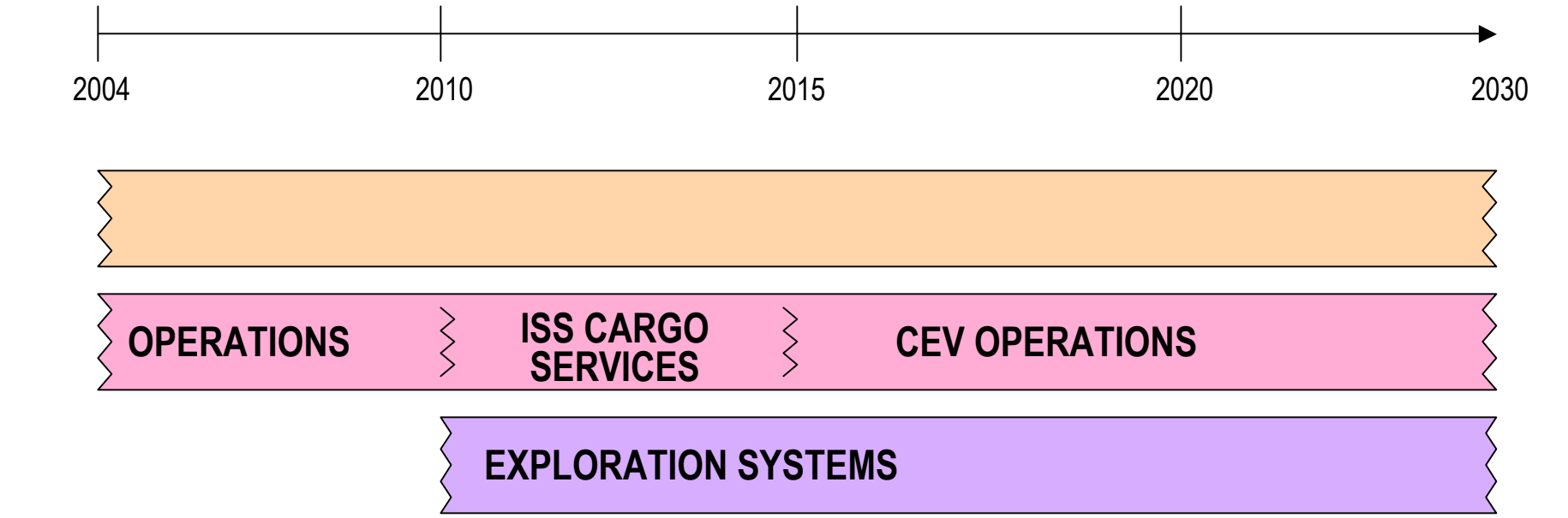
- **The space transportation capabilities necessary to carry out space exploration will be developed consistent with National Security Presidential Directive-31, U.S. Space Exploration Policy, dated January 14, 2004.**

- **Consistent with that direction, the Administrator of the National Aeronautics and Space Administration shall develop, in cooperation with the Secretary of Defense as appropriate, options to meet potential exploration-unique requirements for heavy lift beyond the capabilities of the existing Evolved Expendable Launch Vehicles.**

  - These options will emphasize the potential for using derivatives of the Evolved Expendable Launch Vehicles to meet space exploration requirements. In addition, the Administrator shall evaluate the comparative costs and benefits of a new dedicated heavy-lift launch vehicle or options based on the use of Shuttle-derived systems.

  - The Administrator and the Secretary shall jointly submit to me a recommendation regarding the preferred option to meet future heavy-lift requirements. This recommendation will include an assessment of the impact on national security, civil, and commercial launch activities and the space transportation industrial base.

NASA Space Access



NASA space access requirements evolving with Vision requirements maturity

- Science Missions most mature process and reliance on ELV services for space access
- Space Operations Missions focused on Shuttle safe return to flight and assembly of ISS
  - •Developing plan to retire Space Shuttle after ISS assembly complete near end of decade
  - •Define ISS service requirements and transition from Shuttle-based operations concept
- Exploration Systems Missions in early definition phase
  - Defining Level 1 Requirements
  - Human rating compliance
  - System of Systems definition

NASA Launch Requirements

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SCIENCE

- Robotic
  - Planetary Landers
  - Planetary Orbiters
  - Deep Space
  - Earth Observing
  - Sun-Earth Connection
  - Astrophysics
- Observatories

OPERATIONS

- ISS Crew
- ISS Assembly
- ISS Cargo
- ISS Partner Assets
- Space Communication
- Education payloads
- Reimbursable customers
- CEV Operations

EXPLORATION

- Robotic Precursors
- Technology Demonstrators
- Crew Exploration Vehicle(s)
- Project Prometheus
  - JIMO
- Moon/Mars cargo

Access Considerations

- One of a kind science
- Nuclear propulsion
- Sensitive instruments
- Unique orbits
- Constrained launch periods
- Instantaneous launch windows

- Crew safety and health
- Crew logistics (food/water)
- Pressurized up and down mass
- Automated rendezvous & docking
- Moon/Mars operations

- Crew safety and health
- Crew logistics
- Automated rendezvous & docking?
- In space operations/assembly?
- Nuclear propulsion
- System of system approach

Current Launch Systems

NASA Launch Forecast 2005 Budget

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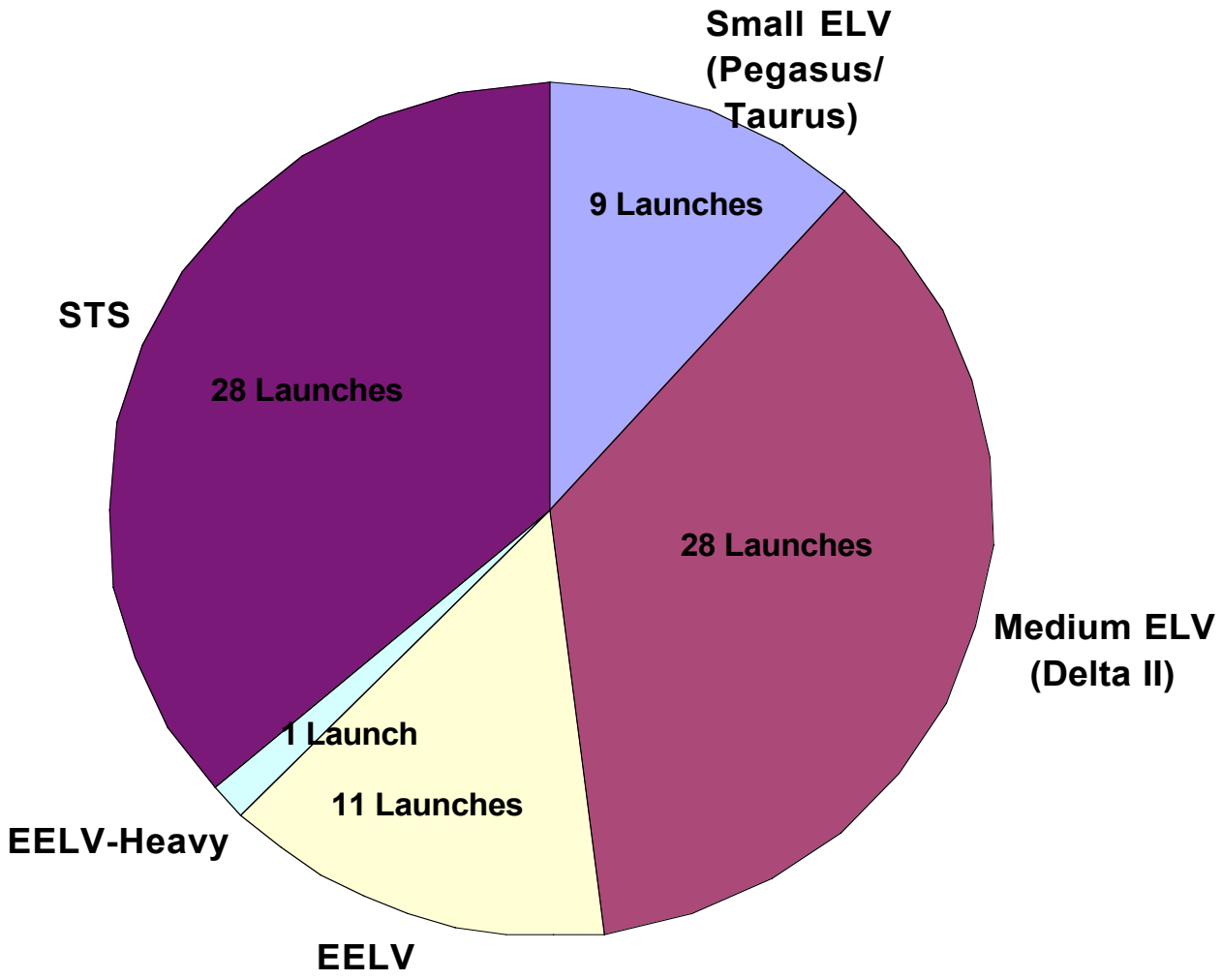
77 Launches



* Assumes Shuttle retirement in 2010, no replacement missions added

Current Small US Launch Capability

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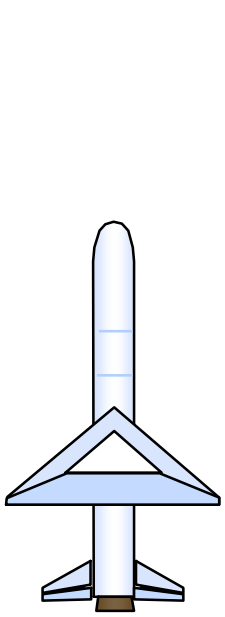

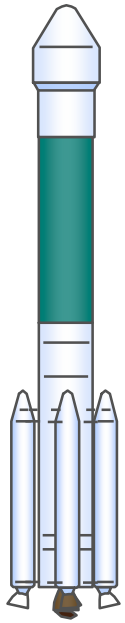
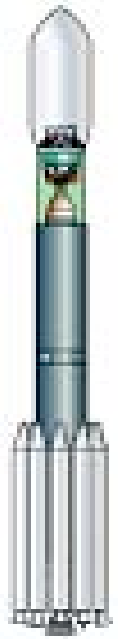
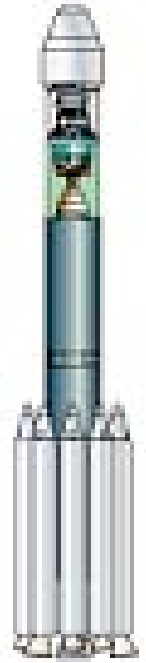

Launch Vehicle	Pegasus	Taurus	Delta II 73XX	Delta II 79XX	Delta II 79XXH
Supplier	Orbital Sciences Corp.	Orbital Sciences Corp.	Boeing	Boeing	Boeing
LEO (kg)	453	568	2,796	5,140	6,000
SSO (kg)	191	302	1,685	3,220	No WTR
ISS (kg)	350	455	2,435	4,440	5,200
GTO (kg)	N/A	N/A	1,000	1,870	2,100
High Energy C3=0	N/A	N/A	725	1,250	1,500
High Energy C3=10	N/A	N/A	600	1,000	1,300

Current Large Class US Launch Capability

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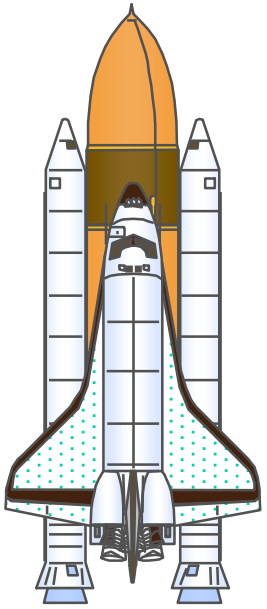


Launch Vehicle	Delta IV 4040	Delta IV 4450	Atlas V 50X	Atlas V 55X
Launch Service	Boeing	Boeing	LM	LM
LEO (kg)	8,600	13,100	9,540	18,000
SSO (kg)	6,300	9,600	No WTR	No WTR
ISS (kg)	7,700	11,800	8,500	17,500
GTO (kg)	3,985	6,345	3,880	8,570
High Energy C3=0	2735	4,580	2680	6330
High Energy C3=10	2115	3,685	2150	5300

Delta IV Heavy
Boeing□
23,165□
21,040□
23,900□
12,650□
9305□
7810□

Space Shuttle
NASA□
22,600□
N/A□
16,800□
2200*□
N/A□
N/A□

* Assumes IUS Upper Stage

NASA Use of EELV

- NASA Science Missions have been cornerstone of NASA ELV Requirements with emphasis on smaller, frequent missions across science disciplines within program cost cap constraints

- EELV capability fits intermediate and larger class missions with less demand…this class of missions tends to be highest value flagship missions

- **NASA EELV Next 5 years(2004-2008)**
  - All missions planned for launch in next five years have contractual launch vehicle assignments 7 EELV class missions over the next five years
    - 3 NOAA/GOES on Delta IV (on- orbit service)
    - MRO mission on contract for launch on Atlas V
    - New Horizons mission on contract for launch on Atlas V
    - Solar Dynamics Orbiter (SDO) on contract for launch on Atlas V

- **NASA EELV Next 10 years (2009- 2013)**
  - NASA potential EELV use for Science missions estimated 1-2/year in outyears
  - Potential EELV support to ISS cargo post- Shuttle retirement in 2010
  - Potential EELV support to Exploration Systems robotic, crew and cargo post- 2010

ELV Evolution

DEVELOPMENT YEARS 1957 - 1963

- Initial Vehicle Development and Test Flights of Converted ICBM Technology
- Birth of the Scout, Delta, Atlas Centaur and Titan Programs

GOLDEN YEARS 1963 - 1979

- US Dominant Provider of Launch Services for All Sectors: Military, Civil, Commercial
- NASA Responsible for Scout, Delta and Atlas Centaur for All Users
- High Flight Rate, With Peaks in Excess of 30 Launches a Year

SHUTTLE YEARS 1980 - 1989

- ELV Production Lines Phasing Down, Closed
- Minimal Government Expenditure on Vehicle Technology, Launch Sites
- USG Payloads Being Transitioned to Shuttle As Primary Mode of Transport
- Ariane Vehicles Positioned to Fill the Gap and Gain Dominant Market Share
- Flight Rate Experiencing Peaks and Valleys

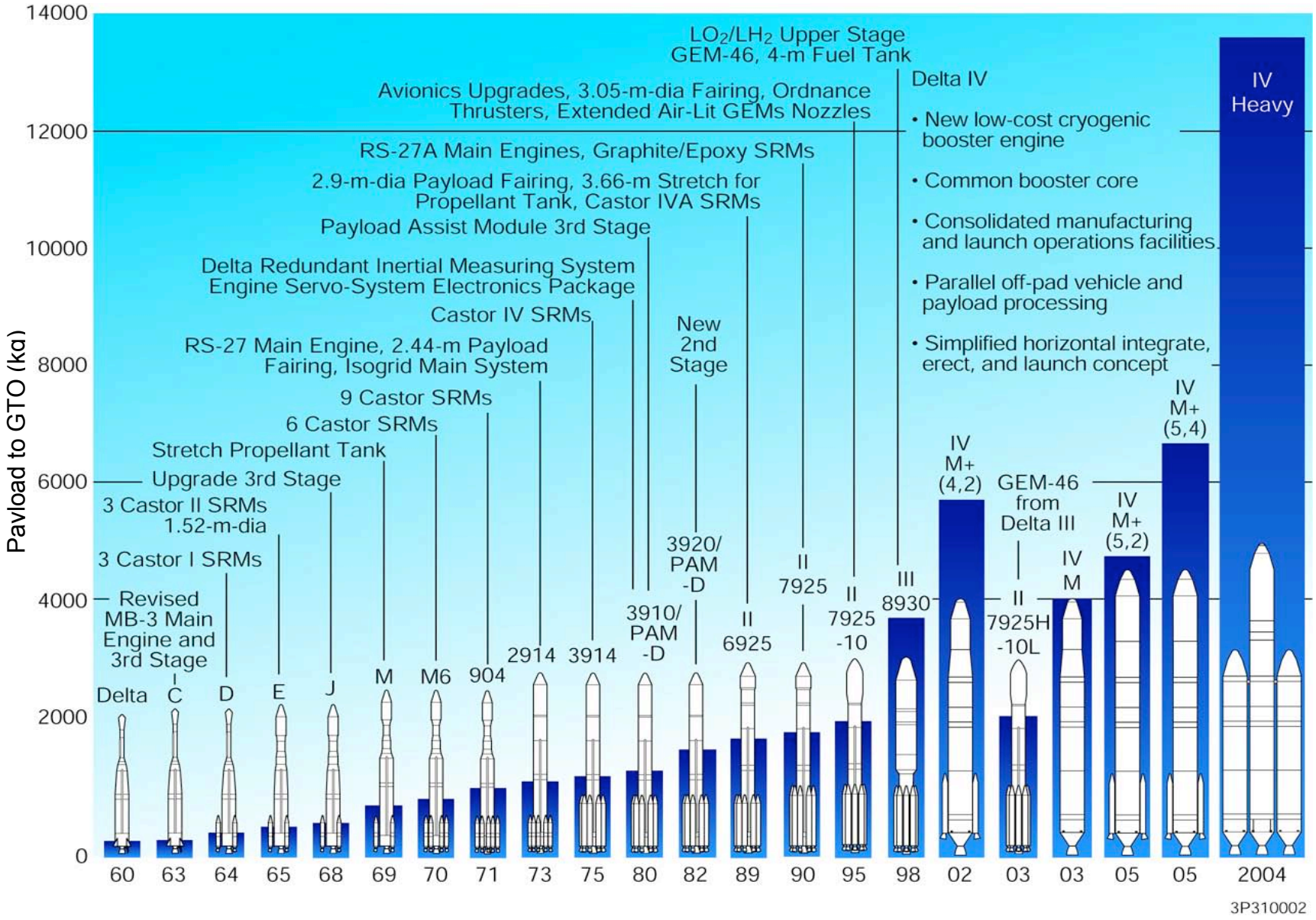
COMMERCIAL Post-Challenger 1989 - 1999

- Government Freeflyer Payloads Transition Back to ELV's
- Increased International Competition, US Never Regains Market Share
- NASA Transitions From Vehicle Operator to Service Purchaser
- Faster, Better, Cheaper Produces Steady State of NASA Launches 6-8yr
- NASA Launch Management and Oversight Consolidated in One Organization

STAGNANT MARKET 2000 - BEYOND

- International Market Has Gone Flat
- Oversupply of International Services in the Larger Vehicle Classes
- US Industry Again Dependent on USG Requirements for Stable Base
- US Industry Investment Capital for Emerging Services Uncertain
- Government required to invest in sustaining capability to assure access

Delta Launch Vehicle Historical Growth Path



Atlas Launch Vehicle Historical Growth Path

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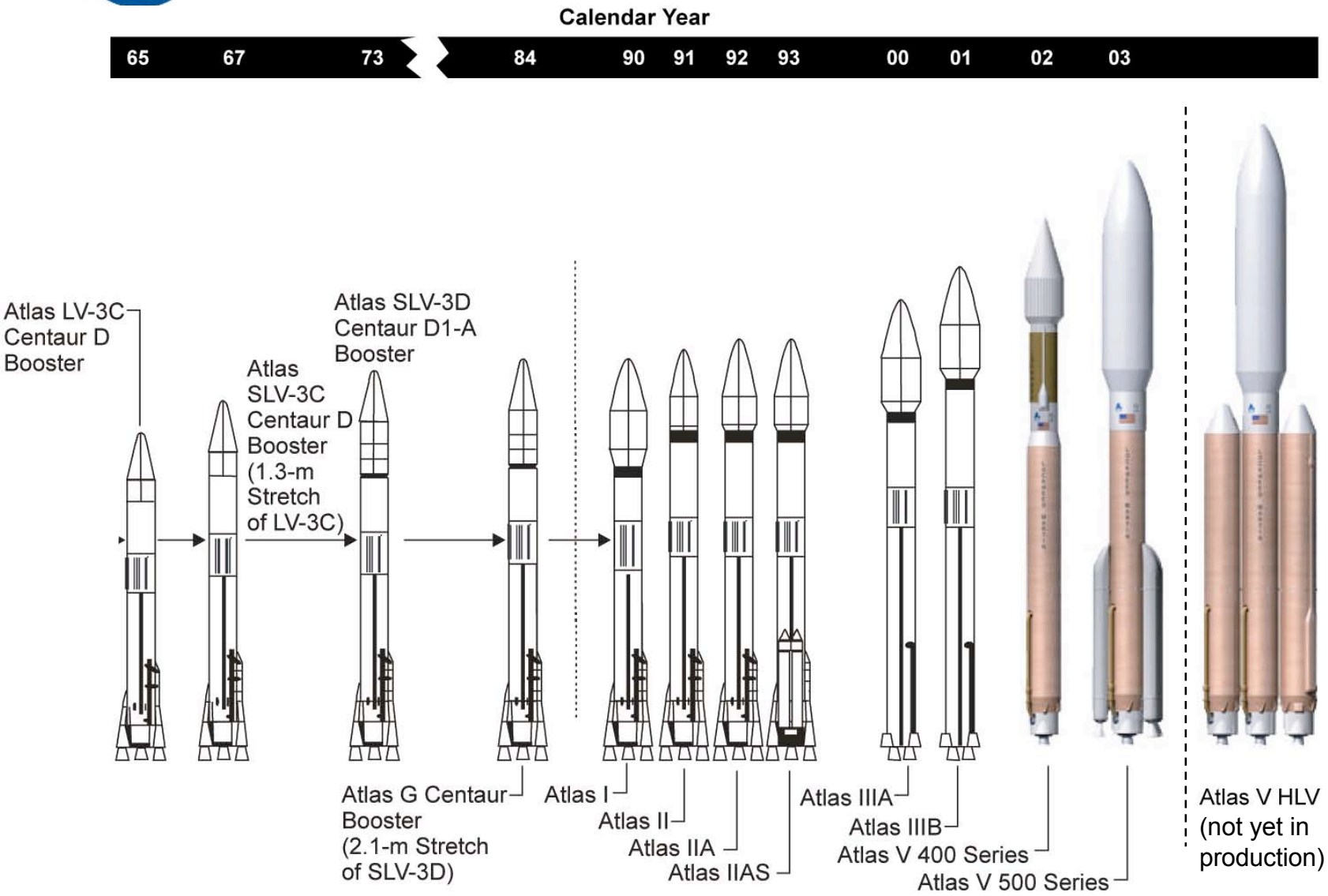

Notional ELV-derived Future Growth Path

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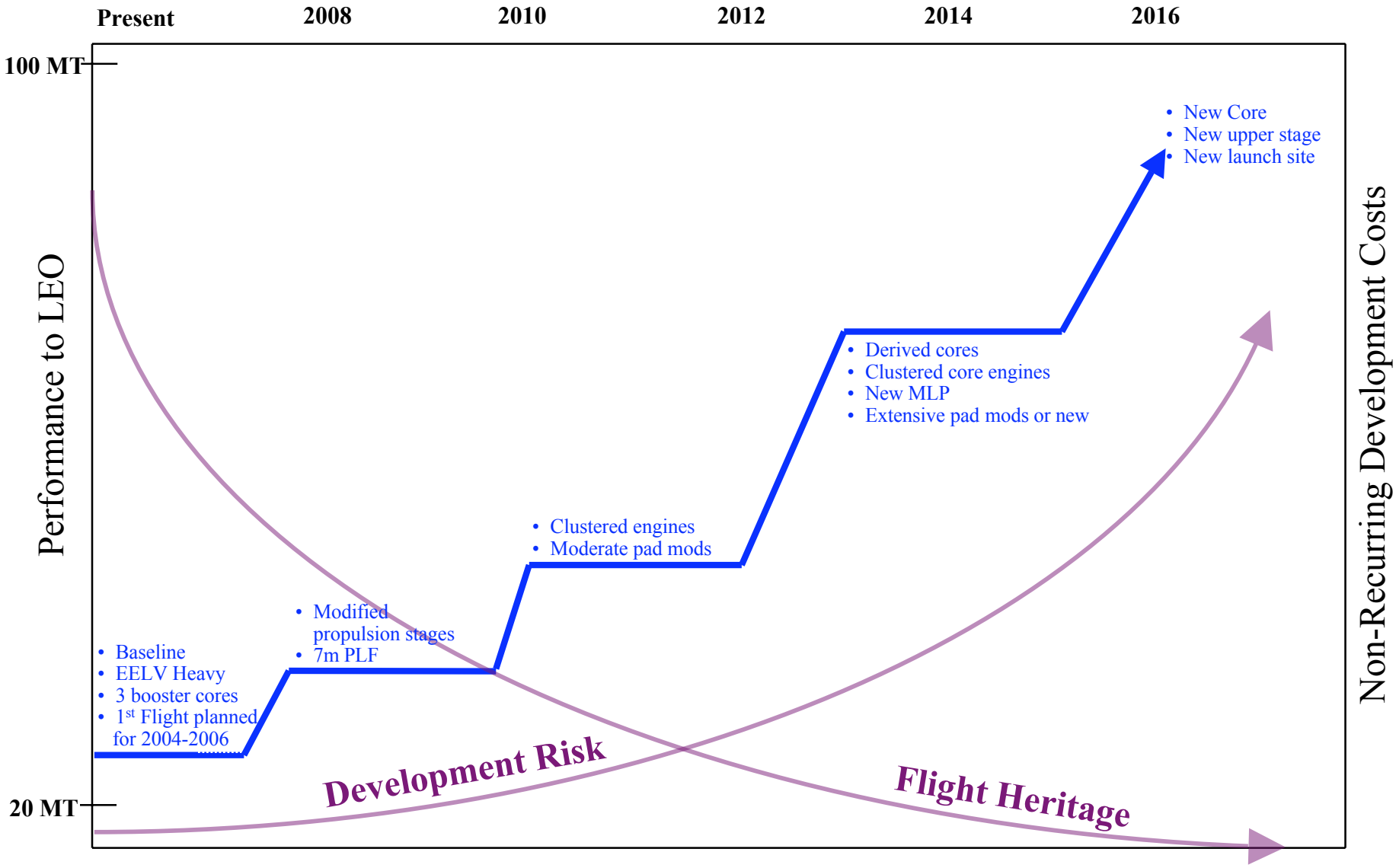

Key EELV Considerations for Heavy-Lift

- EELV systems in initial flight phase..modest enhancements are achievable and within experience….at some point move from evolved system to a new vehicle

- EELV is critical to national security assured access to space--NASA will closely coordinate potential enhancements for reliability and or performance with other government users

- Infrastructure limitations
  - Single Pads for both launch systems, constraint on turnaround times
  - Evolution drives need for major modifications and/or or new infrastructure
  - EELVs not designed to be compatible with Shuttle infrastructure
  - Significant annual production overcapacity exists at present

- Volume limitations – fairing size increases ripple through launch vehicle design and infrastructure

- Multiple launches increases architecture complexity

Shuttle Use : Evolution

EARLY YEARS 1979 - 1986

- Fly All Payloads - Prime US Transportation System
  - NASA
  - Commercial
  - DOD
- Phase Out USG Use of ELV's
- High Projected Flight Rate (60→ 24 / Year)

POST CHALLENGER 1986 - 1998

- Fly All Payloads Requiring STS Unique Capability
  - Offload Commercial Satellites
- Transition USG Free Flyers to Commercial US ELV's
- Use Policy Reduces Flight Rate (6 - 8 / Year)

ISS ASSEMBLY PERIOD 1998 - 2003

- Focus on ISS Assembly, Logistics, Utilization
- Occasional Non-ISS Flight (Chandra, HST SM)
- Use Policy Reduces Flight Rate to 4/year

POST COLUMBIA 2003-2010

- Safely Return to Flight
- Complete Assembly of the International Space Station
- Develop Transition Plan post ISS Assembly complete
- Evaluating potential for future heavy lift

Notional STS-derived Growth Path

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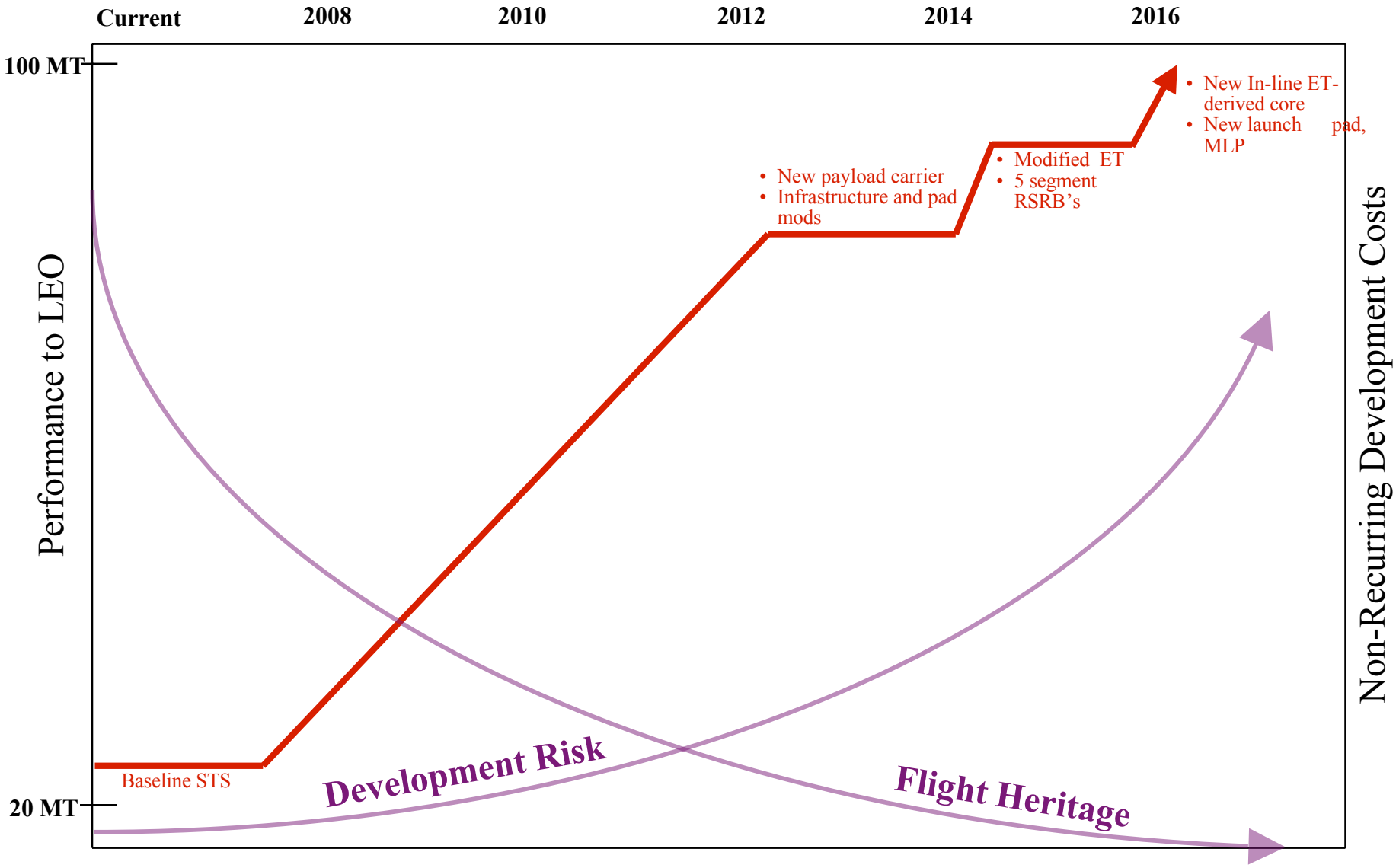


Key Shuttle Considerations for Heavy Lift

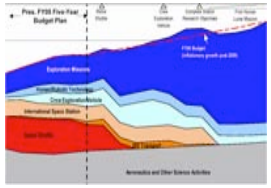
- **Proven systems used for human spaceflight reduces development risks and costs**
  - **Propulsion hardware certification can be a significant technical challenge**
  - **SDV propulsion elements are highly modeled, redundancy to fly humans, have extensive test and flight history, and a heritage of incremental improvements in both operation and manufacturing**
- **Available hardware allows rapid demonstrations, and early flight test capability**
- **Spiral development paths reduce risks as requirements mature and missions evolve**
- **With the retirement of the Orbiter (and related reuse/refurbishment operations) there are viable technical and management approaches to dramatically reduce annual recurring cost**
- **Space exploration will require significant space operations transformation**
  - **Institutional risk of maintaining then transitioning people, facilities, skills, and capabilities**
  - **<u>While</u> meeting challenges of completing the first steps of exploration (RTF, ISS assembly complete, post assembly utilization)**
- **There are enabling resources and options to work with (people, $, skills, and knowledge)**

Human Resource planning

Return to Flight Safely

Facility Utilization

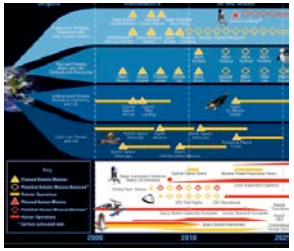
ISS Assembly Complete



Budget Transition
(particularly 08-10)

Post Assembly Utilization with Orbiter Retired

Minimize Risk



Challenge of being able to conduct early demonstrations during this transition phase (2008-2014)

Key Considerations for Shuttle Derived Heavy Lift

- Need to assess Exploration Systems Heavy Lift Requirements Definition with planned Shuttle transition milestones
- Transition of Institutional Capabilities
- Updating Heritage Systems to Expendable Application
- Seek to Minimize Infrastructure Modifications
- Seek to Identify Ways to Lower Operating Cost

Go-Forward Considerations

Advanced Planning

- **Support to ISS**
  - Providing definition of current launch capability to support ISS cargo requirements
  - Identifying options for supporting ISS cargo upon retirement of the Shuttle
    - Mixed fleet assessments for cargo up and down mass
    - Plan to acquire domestic services to augment partner capability

- **Support to Space Exploration**
  - Providing definition of current launch capability to support robotic, cargo and human exploration missions
    - Supported trade studies for OSP and JIMO, provide basis for CEV follow on assessments
    - Updating earlier Shuttle evolution options to address Space Exploration needs
  - Identifying potential vehicle enhancements
    - Reliability and performance
    - Considerations for compliance with human rating
    - Keeping NRO/USAF apprised of issues/trade space- potential for areas of synergy

- **Seek to integrate assured access to space strategy to meet both sets of emerging requirements along with known science needs**
  - Reviewing results from RFI, released in late-2004, soliciting US industry interests /capabilities to meet full range of NASA launch requirements

Commercial Space Transportation RFI

- **RFI identified six categories of future NASA space transportation services requirements**
  - Ground to Low-Earth Orbit Deploy
  - Ground to Interplanetary Trajectory Insertion
  - Ground to Low-Earth Orbit Rendezvous (ISS)
  - Ground to Staging Location
  - Human Transportation and Return
  - In-Space Operations (Transportation Service Node)
- **Received 26 responses**
  - 20 responders addressed some or all six categories
  - Mix of heritage and emerging space entities
  - Offering both domestic and foreign launch options
- **Summary Observations**
  - Appears to be limited opportunity to procure pure commercial-like transportation services beyond free-flyers
    - NASA is sole customer for other uses at this time
  - NASA should be prepared to fund DDT&E costs for any new launch system
    - Current vehicle contractors all have recent bad experience
  - A few emerging launch companies continue to seek to offer commercial services

Space Transportation Challenges

- **NASA Assured Access Strategy**
  - Single or multiple modes of access
    - Crew vs robotic vs cargo
    - Dual compatibility vs dual integration
    - Domestic vs international capability
    - Evolved ELV and/or evolved Shuttle components
  - Reliability, Performance, Human Rating, one or multiple systems
  - Launch Demand, Infrastructure, Requirements, Schedule, Budget
- **Reliability Considerations**
  - Balance with other investments and heritage of current launch systems
- **Human Rating Compliance**
  - What are the CEV requirements….what is the optimal system ?
- **Performance**
  - What requirements can be met with current systems?
  - Where do requirements drive investments?
  - Which evolutionary systems is optimal for crew vs robotic missions?
- **Launch System Infrastructure**
  - CEV and Heavy Lift will drive investments in pad modifications

LV Performance Comparison

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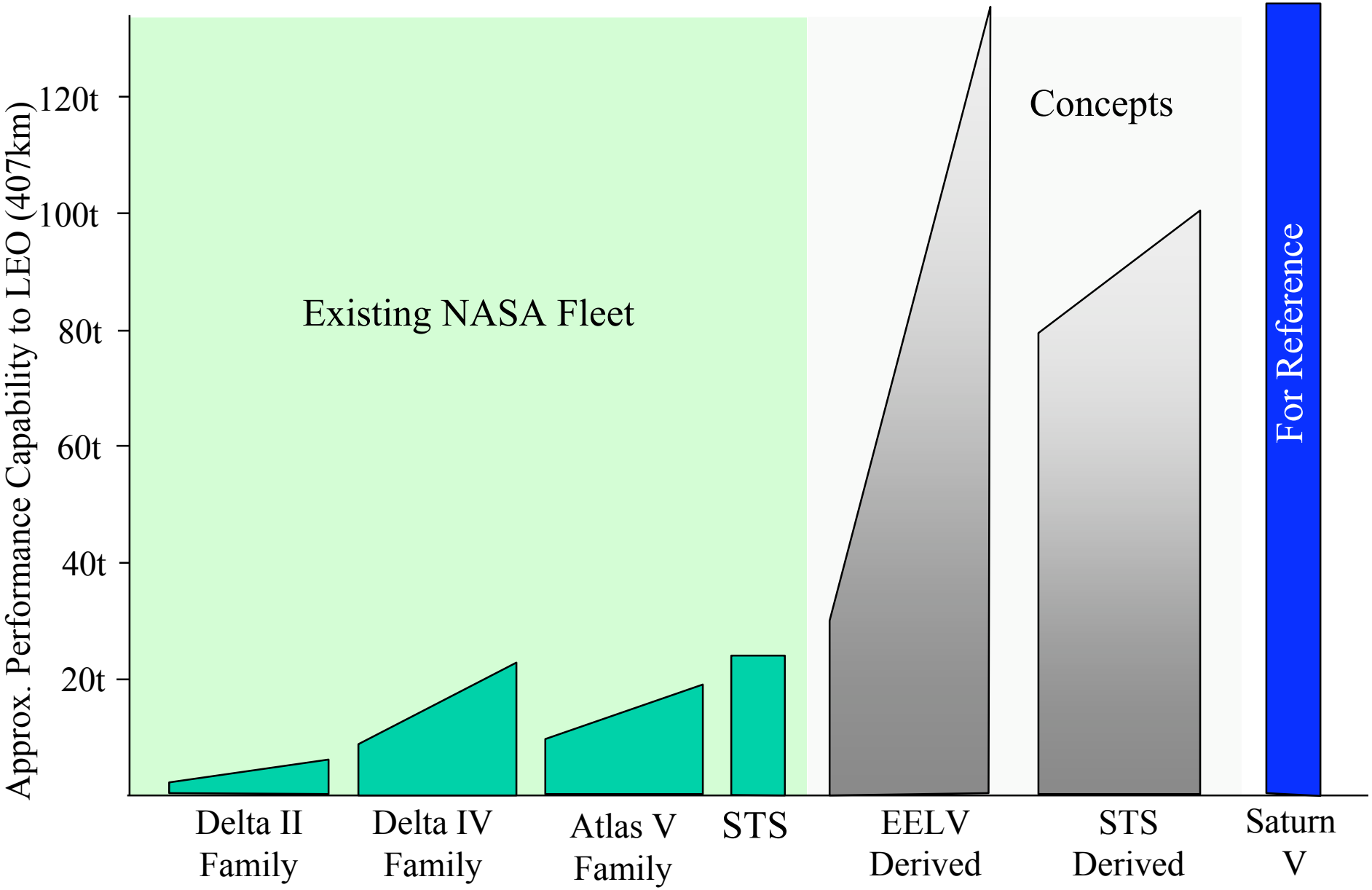

Future Heavy Lift Vehicle Evolution

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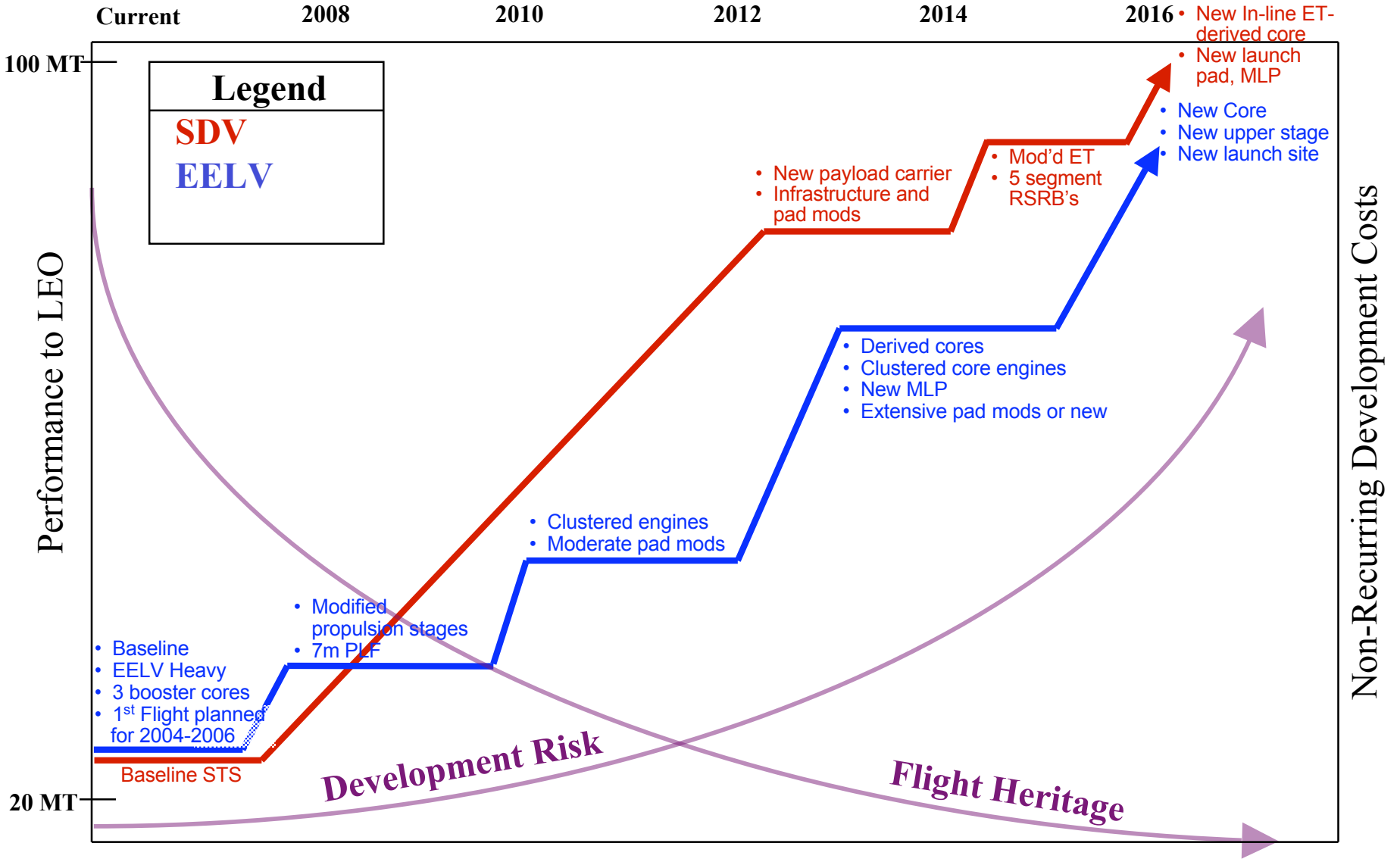

Timing of Future Launch Requirements

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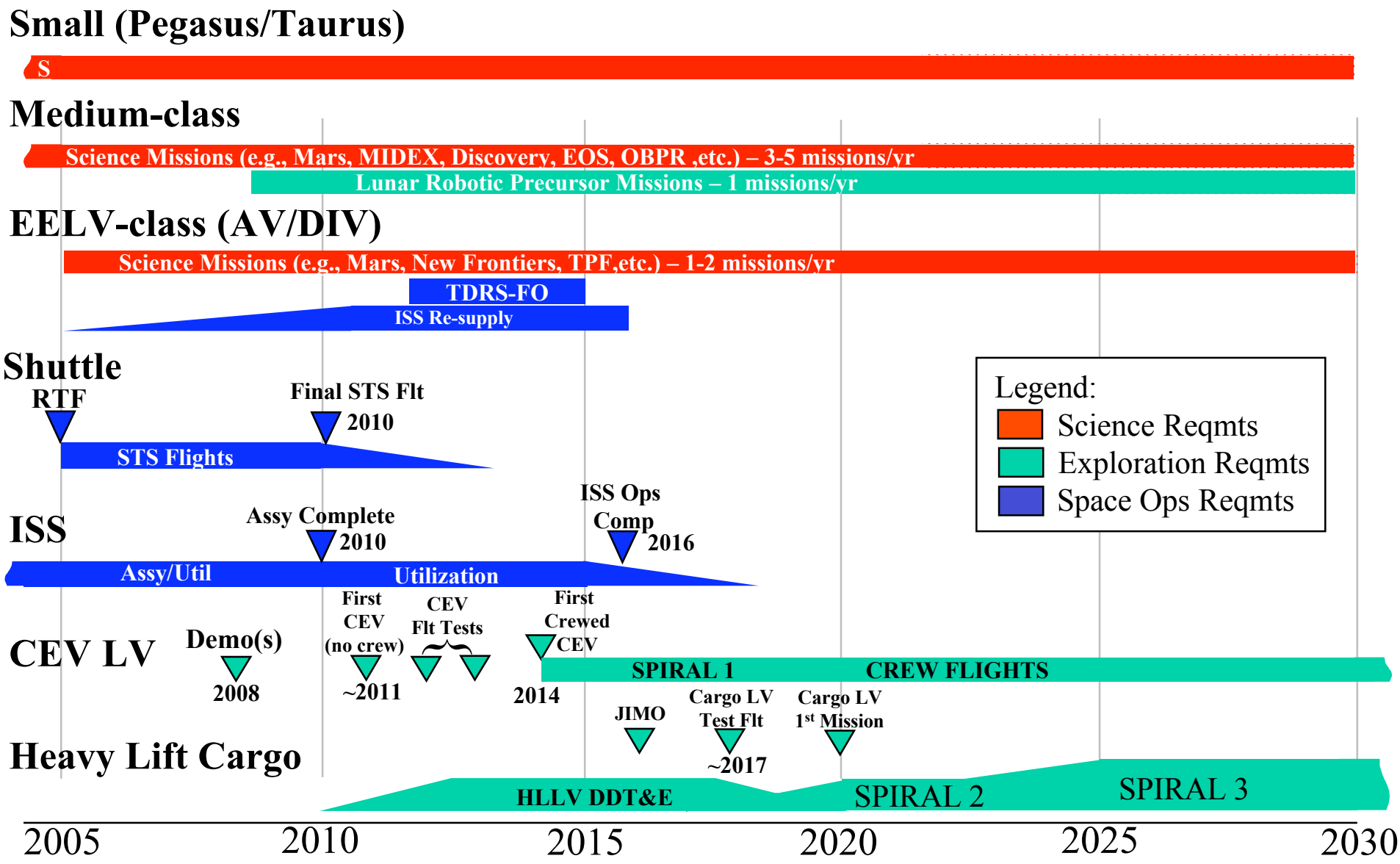

Key Questions for Future Heavy Lift

- When is increased Heavy Lift required?
- How much performance capability is required per flight to optimize mission reliability and cost – balancing in-space operational complexity with LV lift capacity?
- How constrained is the mission opportunity window duration – launch separation sequence frequency?
- Relationship to CEV launch vehicle capability? Same/different LV family?
- Assured access strategy?
- Synergies/Impacts to National Security current/future needs?